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Patentanmeldung Nr. **Patent application No.** **Demande de brevet n°**

04101322.8

PRIORITY DOCUMENT

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Projection system with scanning device

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Projection system with scanning device

The invention relates to a projection system for displaying image information, comprising an illumination system for generating a polarized light beam, a scanning device for scanning the polarized light beam to form an image on a screen and a scan angle enlarger cooperating with the scanning device for enlarging a scanning angle of the polarized light beam.

Such a projection system can be built in a compact way and can therefore be used in small portable electronic equipment such as mobile phones, personal digital assistants (PDA's) and electronic gaming devices.

Such a projection system is known from US 5,751,464. The known projection system can be used for displaying all kinds of information, such as data, video and still pictures. The known device comprises a semiconductor laser, a cylindrical lens having a refracting power in a sub-scanning direction, a reflecting mirror serving as a first image forming system, a polygon mirror rotatable about a center axis serving as an optical deflector, and a first and a second curved mirror serving a second image forming system. In operation, the cylindrical lens is converging the laser beam in the sub-scanning direction and focuses the laser beam on the reflecting surface of the polygon mirror as a line image. Due to the rotation of the mirror about the center of the rotation axis, the polygon mirror in combination with the first and second curved mirror scans and focuses an image on the surface of a screen.
A drawback of the known projection system is that the fixed mirrors need a complicated curved shape and need a relatively large area to operate.

It is an object of the invention to provide a projection system which can be assembled in a relatively easy way and has compact dimensions enabling use in small mobile equipment. In order to achieve this object, the invention provides a projection system as specified in claim 1.

The invention is, inter alia, based on the recognition that in this arrangement the combination of reflections, conversions of the polarization of the reflected light beam and selective transmission of the light beams, the scanning angle of the light beam can be enlarged. The selective reflection of the reflective polarizer enables application of plane, unstructured, optical reflectors and enables a compact way for positioning the mirrors for enlargement of the scan angle. In operation, the reflective polarizer transmits only a linearly polarized light beam with a polarization direction in a first predetermined direction. The quarter-wave plate converts the linearly polarized light from the reflective polarizer in a, for example, laevorotatory circularly polarized light beam and reflects the circularly polarized light beam to the reflective polarizer via the quarter-wave plate. The mirror converts, on reflection, the laevorotatory circular polarization of the light beam in a dextrorotatory circular polarization. The quarter-wave plate converts the dextrorotatory circular polarization of the reflected light beam in a linear polarization directed in the second direction. The reflective polarizer reflects this light beam back to the mirror via the quarter-wave plate. The quarter-wave plate converts the linearly polarized light beam with the polarization direction directed in the second direction into a lightbeam with a dextrorotatory circular polarization. The mirror reflects again the circularly polarized light beam to the reflective polarizer via the quarter-wave plate and converts, upon reflection, the dextrorotatory circular polarization in a laevorotatory circular polarization. The quarter wave plate converts the laevorotatory circular polarization of the reflected light beam in a linear polarization direction having a polarization direction directed in the first direction. The reflective polarizer transmits this linear polarized light beam to a screen. As a result of passing the mirror twice, the light beam leaves the projection device with an angle that equals two times the predetermined angle between the orientation of the mirror and the orientation of both the reflective polarizer and the quarter-wave plate. In this arrangement the quarter-wave plate and the reflective polarizer can be positioned close to the mirror area. Furthermore, the mirror area can be slightly larger than the mirror area needed for a mirror for a single reflection. Therefore, this projection device can be assembled in a relatively easy way in compact dimensions for incorporating this projection device in small portable, electronic devices.

A further embodiment is specified in claim 2. In this arrangement the reflective polarizer is divided in two portions allowing further reflections of the light beam between the respective portion of the reflective polarizer and the mirror for further magnification of the scan angle.

A further embodiment is specified in claim 3. By the addition of one or more third portions in the reflective polarizer, the number of reflection of the light beam between the mirror and the reflective polarizer is further enlarged for a further magnification of the scan angle.

A further embodiment is specified in claim 4. For a maximal contrast the fast axis of the quarter-wave plate can be positioned under an angle of 45 degrees with the polarizing axis of the reflective polarizer.

A still further embodiment is specified in claim 5. Inclination of the mirror with respect to the reflective polarizer and the quarter-wave plate causes that the different order reflections of the light beam will leave the device in different directions.

A further embodiment is specified in claim 6. The angular beam separator filters out zero order and reflections of the light beam having an order higher than two. In this arrangement only the second order reflection of the light beam is used for image forming. The angular beam separator comprises a rectangular slit. Alternatively, this angular filter can be formed by a cylinder lens and a diaphragm.

In a further embodiment the mirror, the quarter-wave plate and the reflective polarizer are provided with flat, unstructured, surfaces.

In a further embodiment the quarter-wave plate and the reflective polarizer are integrated in a single optical component.

A further embodiment is specified in claim 12. A semiconductor laser generates a linearly polarized light beam and can be effectively used in this projection device.

These and other aspects of the invention are apparent from and will be elucidated with reference to the embodiments described hereinafter.

In the drawings:

Fig. 1 shows diagrammatically a first embodiment of the projection device,

Fig. 2 shows details of the first embodiment of scanning mirror, quarter-wave plate and reflecting polarizer,

Fig 3 shows the orientation of the quarter-wave plate and the reflective polarizer,

Fig. 4 shows the inclination of the scanning mirror with respect to the quarter-wave plate and reflecting polarizer,

Fig. 5 shows a second embodiment of scanning mirror, quarter-wave plate and a reflecting polarizer comprising two portions with different polarizing axis, and

Fig. 6 shows a third embodiment of a scanning mirror, quarter-wave plate and a reflecting polarizer comprising three different portions.

Fig 1 shows a first embodiment of a projection system 1 for displaying image information. The projection system 1 comprises an illumination system, for example, a semiconductor laser 3 with a wavelenght of 628 nm for generating a linear polarized light beam with a first polarization direction. In operation, the semiconductor laser 3 may be driven by a data signal 21 for modulating the light beam. Furthermore, the projection system 1 comprises a scanning device formed by a first moveable mirror 5 and an actuator 13 for scanning the light beam in the first or slow direction of the projected image. The first moveable mirror 5 may comprise a galvonometer actuator 13, a piezo actuator or other type of vibrating actuators. In this example, this first, slow direction is parallel to the Y-axis, perpendicular to the plane of the paper.

Alternatevely, instead of the first moveable mirror 5 and the actuor 13 a linear laser array can be applied which laser array comprises for example 128 laser sources on a line which is directed parallel to the Y-axis.

The scanning device further comprises a second rotatable mirror 7, and a drive motor 15 connected via an axis to the second rotatable mirror 7 for scanning the modulated light beam in the second or fast direction parallel to the X-axis to form an image on a screen 35. The second rotatable mirror 7 can be formed by a reflecting surface of a rotatable hexagon connected via the axis to the drive motor 15. Furthermore, the projection device 1 comprises a scan angle enlarger formed by the quarter-wave plate 11 and the reflective polarizer 9 cooperating with the second rotatable mirror 7 for enlarging the scanning angle of the polarized light beam. The polarizing direction of the reflective polarizer is parallel to the first polarization direction of the incoming light beam 27. The reflective polarizar 9 can be formed from a DBEF foil as can be obtained from 3M. Alternatively, a wire grid polarizer can be applied as reflective polarizer. Wire grid polarizers are known per see and can be obtained from Moxtek.

Furthermore, the order can be reversed in which the light beam passes the first mirror for scanning the light beam in the slow scan direction and the second mirror for scanning the light beam in the fast scanning direction.

Fig 2 shows the orientation of the fast axis 10 of the quarter-wave plate 11 with respect to the polarizing axis P1 of the reflective polarizer 9 and the second rotatable mirror 7. For optimal contrast the fast axis 10 of the quarter-wave plate 11 may directed under angle of 45 degrees with the polarization axis P1 of the reflective polarizer 9.

Furthermore, the projection system 1 comprises a data processing and synchronization device 25. In operation, the data processing and synchronization device generates drive signals 23, 25 which are sent to the actuator 13 of the first moveable scanning mirror 5 and the motor 11 of the second rotatable mirror 7 respectively. Furthermore, the data processing and synchronization device generates a data signal 21 for modulating the semiconductor laser 3 depending on the incoming video or data graphics signal 19 and synchronizes the scanning movements of the second rotatable mirror 7 and the moveable mirror 5 with the incoming video signal or data graphics signal 19 in order to project an image on the screen 35.

Fig.3 shows a detailed picture of the reflected and transmitted light beams between the second rotatable mirror 7 and the reflective polarizer 9 via the quarter-wave plate 11. The plane of the reflective polarizer 9 is directed under angle $\alpha 1$ with respect to the second rotatable mirror 7. In operation, an incoming linearly polarized light beam 21 from the semiconductor laser 3 impinges on the second rotatable mirror 7 under an angle $\alpha 1$ with respect to the normal on the surface of the second rotatable mirror 7 via the reflective polarizer 9 and the quarter wave plate 11. The polarization direction of the incoming light beam is directed in a first direction. The reflective polarizer 9, oriented with its polarization axis P1 parallel to the first polarizing direction, transmits the polarized light beam 27 to the second rotatable mirror 7. The quarter-wave plate 11 converts the linear polarization of the light beam 27 in a circular polarization, for example, in a laevorotatory sense. The second rotatable mirror 7 converts the laevorotatory circular polarization of the first light beam in a dextrorotatory circular polarization and reflects the lightbeam 29 to the reflective polarizer 9 via the quarter-wave plate 11. The quarter-wave plate 11 converts the dextrorotatory circular polarization of the reflected light beam 29 in a linearly polarized light beam with a second polarization direction perpendicular to the first polarization direction. The reflective polarizer 9 with is polarizing axis 10 perpendicular to the second polarization direction of the lightbeam 29 reflects this light beam 31 back to the second rotatable mirror 7 via the quarter-wave plate 11. The quarter-wave plate 11 converts the linearly polarized light beam 31 with the second polarization direction into circularly polarized light beam with a dextrorotatory circular polarization. The second rotatable mirror 7 converts the dextrorotatory circular

polarization in a laevorotatory circular polarization and reflects the circularly polarized light beam 33 to the reflective polarizer 9 via the quarter-wave plate 11. The quarter wave plate 11 converts the laevorotatory circular polarization of the reflected light beam in linearly polarized light beam with the first polarization direction. The reflective polarizer 9 with its polarizing axis parallel to the polarization direction of the reflected light beam 33 transmits this reflected light beam as an departing light beam 33 to the screen 35. The angle $\alpha2$ of this departing light beam with respect to the incoming light beam 27 is $4\alpha1$. In this arrangement the scan angle β is doubled with respect to the angle $2\alpha1$ as may obtained in a conventional projection device with the scanning mirrors but without scan angle enlarger comprising the reflective polarizer 9 and quarter-wave plate 11.

In a further embodiment the quarter-wave plate 11 can be integrated with the reflective polarizer 9 by providing a phase retarding layer on the reflective polarizer. Furthermore, the rotatable mirror 7 and the reflective polarizer 9 may have flat surfaces. In this embodiment the quarter-wave plate 11 and the reflective polarizer 9 can be positioned close to the rotatable mirror 7 and hence the area of the rotatable mirror 7 can be nearly equal to that for conventional usage having only a single reflection and a compact projection device can be obtained. The orientation of the second rotatable mirror 7, the quarter-wave plate 11 and the reflective polarizer 9 may be parallel to the YX-plane.

Fig. 4 shows an arrangement of the rotatable mirror 7, the quarter-wave plate, the reflective polarizer and an angular beam separator. The angular beam separator is formed by the inclination of the rotatable mirror 7 with respect to the YX plane while the quarter-wave plate 11 and the reflective polarizer 9 remains directed parallel to the YX-plane. Furthermore, a rectangular aperture or slit 37 is positioned between the reflective polarizer 9 and the screen 35. The longitudinal direction of the slit is directed parallel to the X-axis. As a result of the vertical inclination of the rotatable mirror 9 with respect to the reflective polarizer 9, the different passes of the reflected light beam emerge at different angles and can be filtered out by the slit 27. This angular beam separator reduces a zero order pass, 1st pass, 3rd pass and higher passes of the light beam due to imperfections of the quarter-wave plate 11 and the reflective polarizer 9. Furthermore, instead of a rectangular slit, a cylinder lens 38 and a diaphragm 39 can be applied for transmitting only the wished reflection of the light beam. The axis of the cylinder lens is directed parallel to the Y-axis.

Fig 5 shows a further embodiment of the scan angle enlarger of the projection system. This embodiment comprises a reflective polarizer 9, a quarter-wave plate 11 and the second rotatable mirror 7. In this embodiment the reflective polarizer 9 comprises a

rectangular first portion 91 and a rectugular second portion 92 whereby the polarizing direction of the first portion 91 is parallel to the polarization direction of the incoming linearly polarized light beam 27 from the rotatable mirror 7. Furthermore, the polarizing direction of the second portion 92 is parallel to the polarization direction of the departing light beam, whereby the polarizing axis of the first and second portions 91,92 are mutual perpendicular.

In operation, an incoming linearly polarized light beam 21 from the semiconductor laser 3 impinges on the second rotatable mirror 7 under an angle $\alpha 1$ with respect to the normal on the surface of the second rotatable mirror 7 via the first portion 91 of the reflective polarizer 9 and the quarter wave plate 11. The polarization direction of the incoming light beam is directed in the first direction. The first portion 91 of reflective polarizer 9, oriented with its polarization axis parallel to the first polarizing direction of the incoming linearly polarized light beam 27, transmits the linearly polarized light beam 27. The quarter-wave plate 11 converts the linear polarization of the light beam 27 in a circular polarization, for example, in a laevorotatory sense. The second rotatable mirror 7 converts the laevorotatory circular polarization of the first light beam in a dextrorotatory circular polarization and reflects the light beam 29 to the first portion 91 of the reflective polarizer 9 via the quarter-wave plate 11. The quarter-wave plate 11 converts the dextrorotatory circular polarization of the reflected light beam 29 in a linearly polarized light beam with a second polarization direction perpendicular to the first polarization direction. The first portion 91 of the reflective polarizer 9 with is polarizing axis perpendicular to the second polarization direction of the lightbeam 29 reflects this light beam 31 back to the second rotatable mirror 7 via the quarter-wave plate 11. The quarter-wave plate 11 converts the linearly polarized light beam 31 with the second polarization direction into a circularly polarized light beam with a dextrorotatory polarization. The second rotatable mirror 7 converts the dextrorotatory circular polarization in a laevorotatory circular polarization and reflects the circularly polarized light beam 33 to the second portion 92 of the reflective polarizer 9 via the quarter-wave plate 11. The quarter wave plate 11 converts the laevorotatory circular polarization of the reflected light beam in a linear polarization directed in the first polarization direction. The second portion 92 of the reflective polarizer 9 with its polarizing axis perpendicular to the first polarization direction of the light beam 33 reflects this light beam back to the second rotatable mirror 7 via the quarter-wave plate 11. The quarter-wave plate 11 converts the linearly polarized light beam 31 with the second polarization direction into a circularly polarized light beam with a laevorotatory circular polarization. The second rotatable mirror 7

converts the laevorotatory circular polarization in a dextrorotatory circular polarization and reflects the circularly polarized light beam 33 to the second portion 92 of the reflective polarizer 9 via the quarter-wave plate 11. The quarter wave plate 11 converts the dextrorotatory circular polarization of the reflected light beam in a linear polarization directed in the second polarized direction. The second portion 92 of the reflective polarizer 9 with its polarizing axis parallel to the second polarization direction transmits the lightbeam as a departing light beam 43. In this arrangement the scan angle χ is multiplied 3 times with respect to the scan angle $2\alpha1$.

A larger magnification of the scan angle can be obtained in an embodiment wherein the reflective polarizer comprises one or more third portions of the reflective polarizer between the first and second portions. In this embodiment the third portions are arranged such that the polarizing axis of the respective portions, receiving the reflected light beams from the rotatable mirror, are directed perpendicular to the polarizing direction of the respectively reflected light beams.

Fig. 6 shows a further embodiment of the scan angle enlarger of a projection system comprising a reflective polarizer 9, a quarter-wave plate 11 and the second rotatable mirror 7. In this embodiment the reflective polarizer 9 comprises two rectangular first and second portions 93,95, whereby the polarizing direction of the first portion 93 is parallel to the polarization direction of an incoming linearly polarized light beam 27 from the mirror 5. The polarizing direction of the second portion 95 coincides with the polarization direction of the departing linearly polarized light beam. Furthermore, the reflective polarizer 9 comprises a third rectangular portion 94 between the first and second portion 93,95. The polarizing axis of the third portion 95 is perpendicular to the polarizing direction of the linearly polarized light beam 43 reflected a third time from the second rotatable mirror 7.

Operation of this embodiment is simular to that of the embodiment described with respect to Fig. 5, except that after reflecting a third time from the second rotatable mirror 7 of the linearly polarized lightbeam, the third portion 95 reflects the linearly polarized light beam back to the second rotatable mirror 7 via the quarter-wave plate 11, because the polarizing axis of the reflective polarizer is perpendicular to the polarization direction of the light beam 43. The quarter-wave plate 11 converts the linear polarization of the light beam 45 in a dextrorotatory circular polarization. The second rotatable mirror 7 converts the dextrorotatory circular polarization in a leavorotatory polarization and reflects the circularly polarized light beam to the third portion 95 of the reflective polarizer 9 via the quarter-wave plate 11. The quarter-wave plate 11 converts the leavorotatory polarization of

the reflected light beam in a linear polarization directed in the second direction. The polarizing direction of the second portion 95 of the reflective polarizer 9 is parallel to the second polarizing direction of the reflected linearly polarized light beam and transmits the light beam as departing light beam 47. In this arrangement the scan angle δ is multiplied 4 times with respect to the scan angle 2α.

In this embodiment the quarter-wave plate may integrated with the second rotatable mirror for allowing image projection with a finite cross-section of the light beam.

A projection system is disclosed for displaying image information comprising an illumination system for generating a light beam, a scanning device comprising a mirror for scanning the generated light beam to form an image on a screen, and a scan angle enlarger cooperating with the scanning device for enlarging a scanning angle of the generated light beam. The scan angle enlarger comprises a reflective polarizer, a quarter-wave plate and the mirror arranged to reflect the light beam at least one between the reflective polarizer and the mirror via the quarter-wave plate. This arrangement enables a compact assembly of the projector device for use in small portable devices such as mobile phones and PDA's.

It will be obvious that many variations are possible within the scope of the invention without departing from the scope of the appended claims.

CLAIMS:

1. A projection system (1) for displaying image information comprising:

an illumination system (3) for generating a light beam,

a scanning device (5,13,7,15) comprising a mirror (5,7) for scanning the light beam to form an image on a screen (35), and

a scan angle enlarger (7,9) cooperating with the scanning device for enlarging a scan angle of the polarized light beam,

characterized in that the scan angle enlarger comprises a reflective polarizer (9), a quarter-wave plate (11) and the mirror (7) arranged to reflect the light beam at least once between the reflective polarizer (9) and the mirror (7) via the quarter-wave plate.

2. A projection system as claimed in claim 1 wherein the reflective polarizer (9) comprises a first portion (91) and a second portion (92) whereby the polarizing axis of the first portion is perpendicular to the polarizing axis of the second portion.

3. A projection system as claimed in claim 2 wherein the reflective polarizer (9) comprises one or more third portions (94) positioned between the first and second portions (93,95) wherein the polarizing axis of the one or more portions is perpendicular to a polarization direction of one or more respectively reflected light beams received by the respective one or more third portions from the mirror (7).

4. A projection system as claimed in claim 1 wherein the orientation of the fast axis of the quarter-wave plate (10) is directed under an angle of 45 degrees with the polarizing axis (P1) of the reflective polarizer (9).

5. Projection system as claimed in claim 1 wherein the orientation of the reflective polarizer (9) and the orientation of the quarter-wave plate (11) are directed in a first plane parallel to the first and second axis, the second axis being perpendicular to the first axis, and the orientation of the mirror (7) is directed in a second plane parallel to the first axis

and under a predetermined inclination angle θ with respect the second axis for directing higher order reflections of the light beam in different direction from the mirror.

6. A projection system as claimed in claim 1 wherein the projection system is provided with an angular beam separator (37) positioned between the reflective polarizer (11) and the screen (35) for transmitting a predetermined order of reflection of the light beam.

7. A projection system as claimed in claim 6 wherein the angular beam separator (37) is provided with a rectangular aperture having its long axis directed parallel to the first axis.

8. A projection system as claimed in claim 6 wherein the angular beam separator comprises a cylinder lens and a diaphragm.

9. A projection system as claimed in claim 1 wherein the mirror (7), the quarter-wave plate (11) and the reflective polarizer (9) are flat, unstructured, optical elements.

10. A projection system as claimed in claim 1 wherein the quarter wave plate (11) and the reflective polarizer (7) are integrated in a single optical element.

11. A projection system as claimed in claim 1 wherein the illumination system (3) comprises a semiconductor laser for generating a linearly polarized light beam.

12. A projection system as claimed in claim 1 wherein the mirror (7) is formed by a reflecting surface of a rotatable hexagon.

13. A projection system as claimed in claim 1 wherein the projection system comprises a modulating device (17) for modulating the polarized light beam.

ABSTRACT:

A projection system for displaying image information comprising an illumination system for generating a light beam, a scanning device comprising a mirror for scanning the generated light beam to form an image on a screen, and a scan angle enlarger cooperating with the scanning device for enlarging a scanning angle of the generated light beam. The scan angle enlarger comprises a reflective polarizer, a quarter-wave plate and the mirror arranged to reflect the light beam at least one between the reflective polarizer and the mirror via the quarter-wave plate. This arrangement enables a compact assembly of the projector device for use in small portable device such as mobile phones and PDA's.

Fig. 1

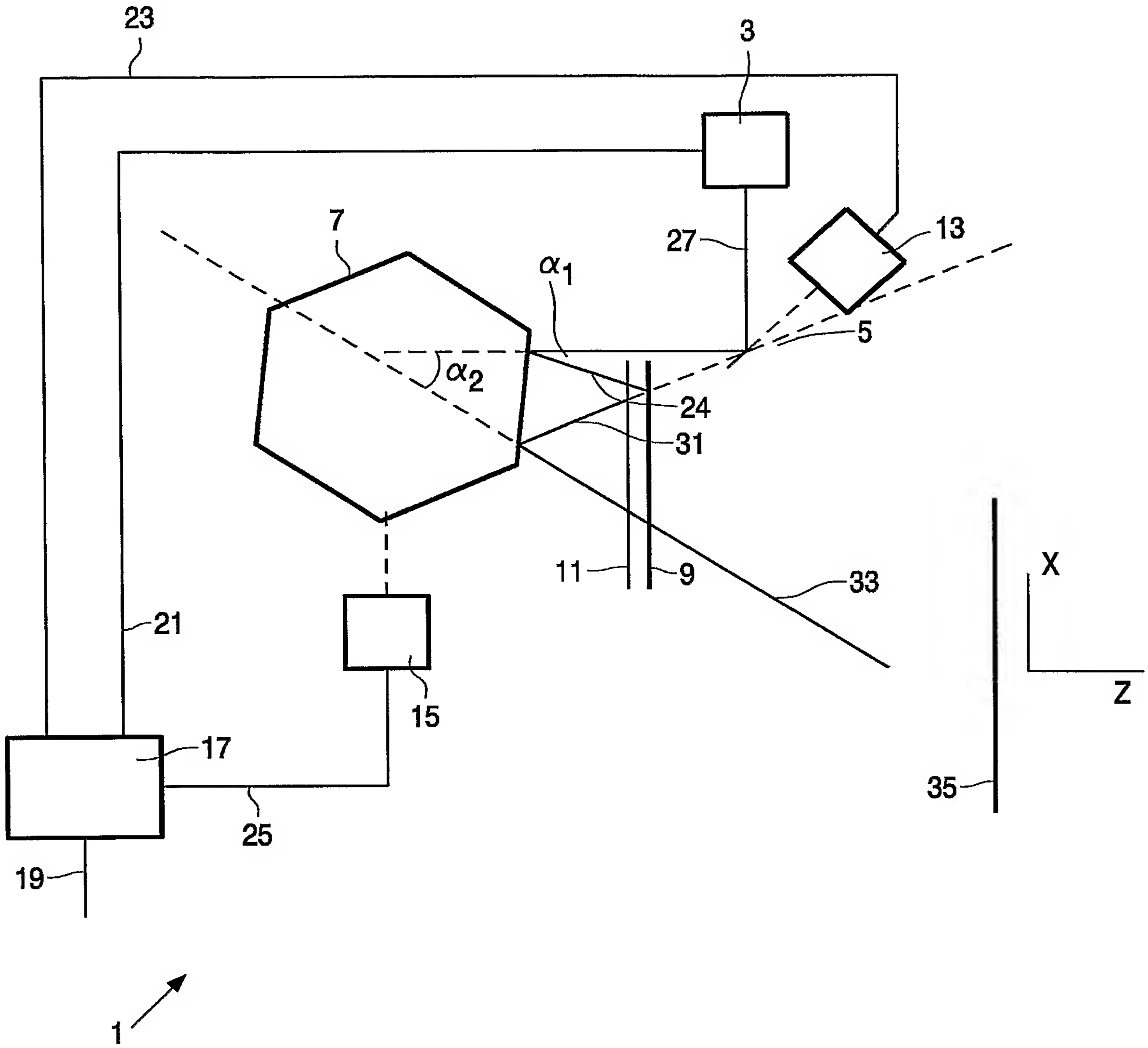

FIG. 1

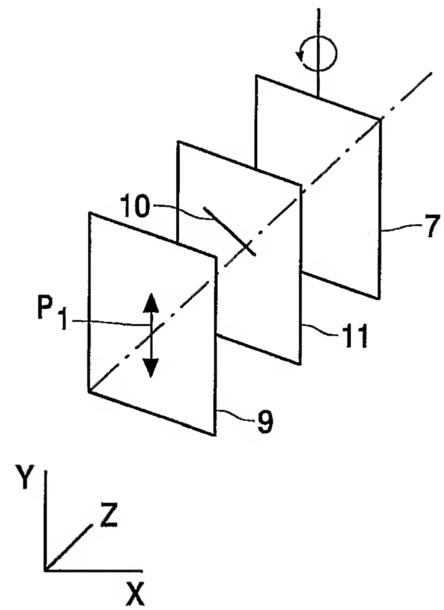

FIG. 2

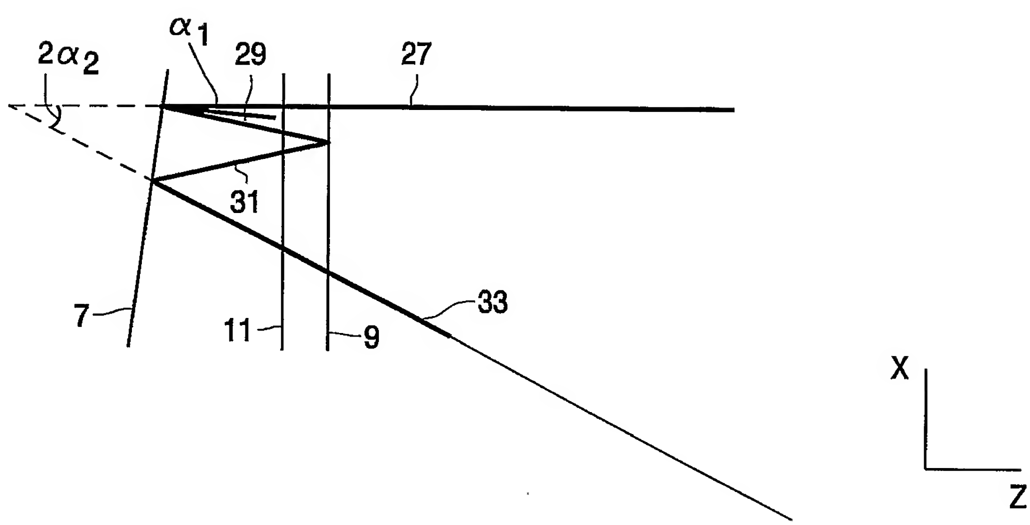

FIG. 3

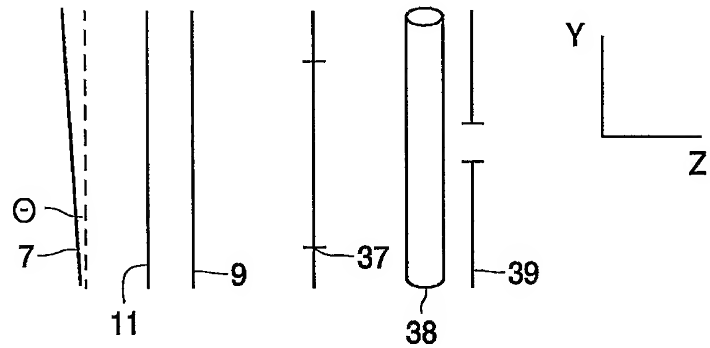

FIG. 4

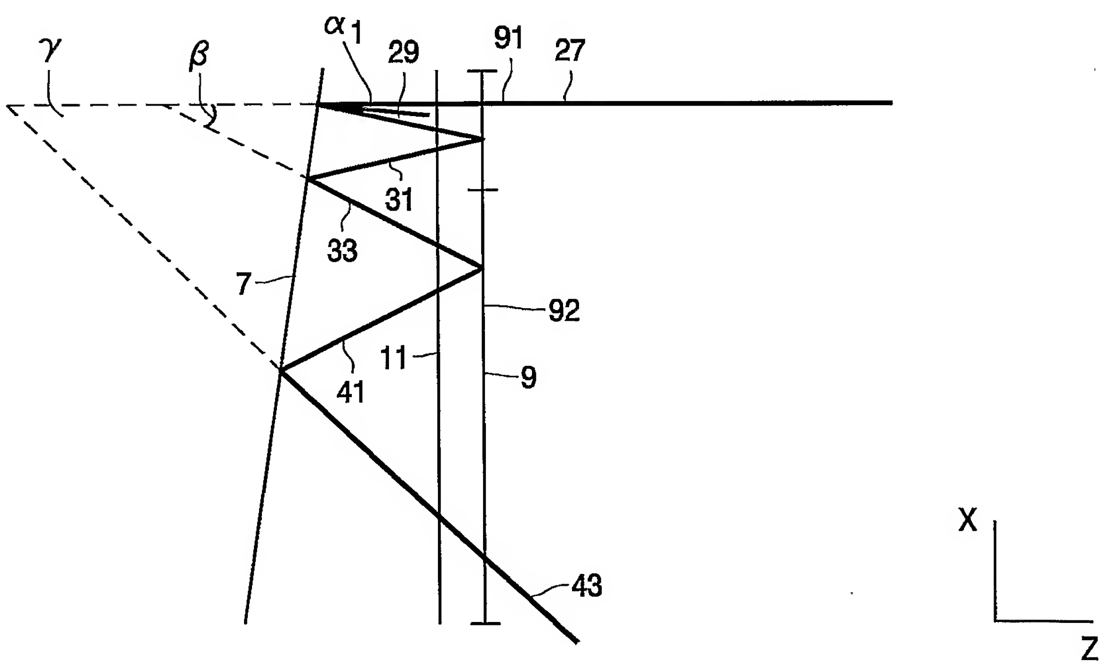

FIG. 5

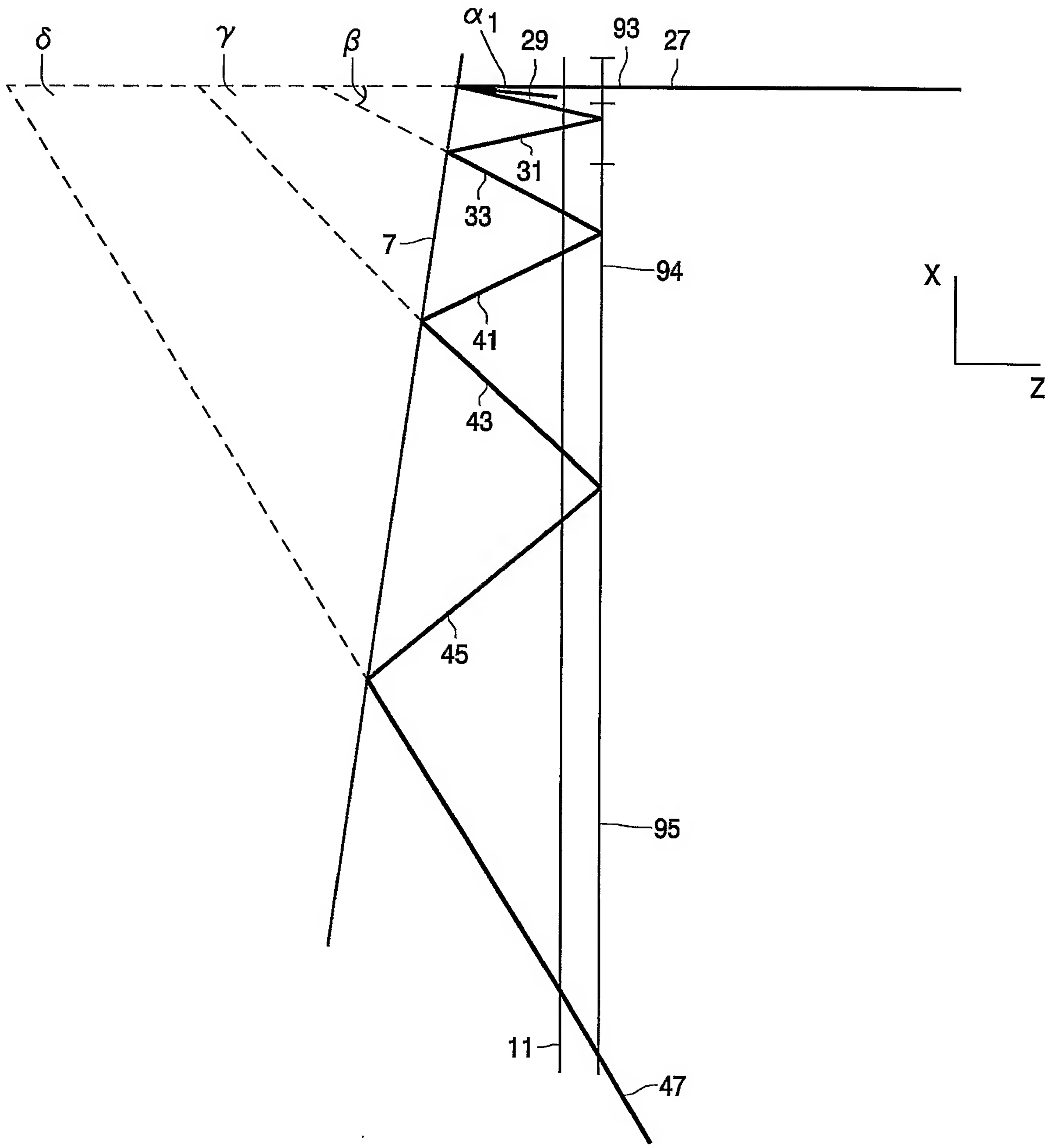

FIG. 6